EXECUTIVE SUMMARY

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Introduction

Under the direction of the U.S. Environmental Protection Agency (EPA), the Quendall Terminals owners (Altino Properties, Inc. and J.H. Baxter & Company; the Respondents) are conducting a Remedial Investigation (RI) and Feasibility Study (FS) at the Quendall Terminals Site (Site). The RI/FS is being conducted in accordance with the Site Administrative Settlement Agreement and Order on Consent (AOC; EPA 2003a), pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The RI Report (Anchor QEA and Aspect 2012) was provided to EPA on March 19, 2012.

The purpose of this FS is to develop and evaluate a range of remedial alternatives that protect human health and the environment, and maintain that protection over time. EPA, in consultation with other agencies and with public input, will use the information in the RI and FS Reports to select a remedial action, which will be documented in a Record of Decision (ROD), in accordance to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP; 40 Code of Federal Regulations (CFR) 300).

Site Description and Source Areas

The Site is located on the southeast shore of Lake Washington, in Renton, Washington (Figure ES-1), within a former industrial area that now includes residential and commercial uses. The Site encompasses approximately 51 acres and includes the Quendall Terminals Property located at 4503 Lake Washington Boulevard North, a portion of Lake Washington immediately adjacent to the Quendall Terminals Property, and a portion of the Burlington Northern Railroad right-of-way to the east (referred to as the Railroad Property). The upland portion of the Site encompasses approximately 22 acres and is relatively flat, with approximately 1,500 feet of Lake Washington shoreline. Aquatic lands that are part of the Site are either owned privately or owned by the State of Washington. The lake area within and adjacent to the Site is considered prime habitat for the rearing of juvenile salmonid stocks, including Chinook salmon, which are listed as threatened under the Endangered Species Act (ESA).

Shortly after water levels in Lake Washington were lowered in 1916, Reilly Tar & Chemical Company developed the Quendall Terminals Property as a creosote manufacturing facility. In 1971, the property was sold to Quendall Terminals and the upland property was used intermittently to store diesel fuel and crude/waste oils. Fuel and oil storage operations ceased in 1983 when the last storage tanks were demolished. From approximately 1977 to 2009, the Site was primarily used for log sorting and storage.

Figure ES-1 shows the locations of historical Site features. Coal and oil-gas tar residue (collectively referred to as coal tars) were distilled into three fractions that were shipped off the Site. Releases of coal tars and distillate products to the environment occurred where product transport, production, storage, and/or disposal were performed. Five general release areas have been identified, as follows:

- Offshore, along the former T-Dock, coal tar feed stock was offloaded and transferred to Site uplands through a pipeline located on the dock deck. A large spill occurred sometime between 1930 and 1940 at the western end of the T-Dock during vessel offloading. Elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) in surface sediments along the main stem of the T-Dock indicate that there also may have been spills from leaks in the piping.
- Around the former Still House, coal tar was distilled, and creosote and light distillates were transferred to surrounding tanks via piping. Reported releases include product releases directly onto the earthen floor of the former Still House.
- The former Railroad Tank Car Loading Area at the railroad tracks east of the former Still House was situated on a trestle built over May Creek and is a location of apparent historical spills.
- The former May Creek Channel, located south of the manufacturing plant and storage tanks, received wastes from historical operations. Wastes from nearby tanks were reportedly placed in the eastern portion of the former channel, and the western portion of the former channel reportedly received creosote wastes discharged from the former Still House sewer outfall.
- The north and south sumps received effluent from the former Still House cooling lines, and this effluent sometimes contained creosote and tars.
- Quendall Pond, located near the shoreline, was constructed in an area where tank bottoms from nearby storage tanks were placed. This area also received wastes from North Sump overflows. Waste from Quendall Pond has migrated into adjacent Lake Washington.

Some solid wastes produced in the manufacturing process were also disposed of at the Site. Heavy tar produced by the distillation process was cooled and solidified in pitch bays located north of the former Still House. The waste pitch was chiseled out and reportedly placed near the shoreline. Solid tar products have also been observed in shallow soils around the northern railroad loading area, where solid products were loaded onto railcars.

Geology and Hydrogeology

The Site is located within the Puget Sound Lowland, a physiographic feature dominated by repeated advances and recessions of glacial ice. Much of what is now the upland portion of the Site was formed by the lowering of the water level of Lake Washington in 1916, which exposed the alluvial delta of May Creek. Site topography has been modified over the past 90 years by filling and grading activities. Site geologic units are illustrated in the cross section on Figure ES-2. Geologic units include the following:

- **Fill.** Present at the ground surface and ranges from 1 foot to more than 10 feet thick. The Fill Unit is a mixture of silt, sand, and gravel as well as wood debris, glass, brick, and pitch-like materials. Wood chips and bark from former log sorting operations are common in the upper few feet.
- **Shallow Alluvium.** Extends from the base of the Fill Unit to depths of between 30 and 50 feet below ground surface (bgs). The Shallow Alluvium was deposited as a series of gently dipping beds consisting of very soft peat and organic silts interbedded with very loose, silty, fine to medium sand. As a result of their depositional history, including repeated slumping, the discontinuous layers generally slope downward toward the west and northwest.
- **Deeper Alluvium.** Extends from the base of the Shallow Alluvium to depths of between 90 and 140 feet bgs. The Deeper Alluvium generally consists of more homogeneous, coarser materials including medium dense to dense sand and gravel. Near the top of the Deeper Alluvium, lower-permeability interbedded silt to silty sand layers are also present, and are most likely a transitional zone representing the continuation of the May Creek delta. Silty sand layers have been observed as deep as 83 feet bgs.
- **Lacustrine Clay.** Beneath the Deeper Alluvium, a layer of lacustrine clay at least 10 feet thick has been encountered at depths below 90 feet bgs.

The lake bottom substrate is typically a fine silt/mud, although there are several areas with a sandier bottom, including a sandspit north of the former T-Dock and sediment near the outer harbor line south of the former T-Dock. With the exception of a wood-debris area along the southern shoreline, aquatic vegetation is dominated by dense areas of Eurasian water milfoil.

The majority of the Site hydrocarbon contamination, including dense non-aqueous phase liquids (DNAPL), is present within the Shallow Alluvium. Evidence from field observations suggests that interbedded, low-permeability layers in the Shallow Alluvium can stop, slow, or alter migration of DNAPL.

Hydrogeologic units affected by Site contamination include the following:

- **Shallow Aquifer.** Occurs in the Fill Unit and in the Shallow Alluvium to depths of approximately 30 to 50 feet bgs, with the water table typically encountered at depths of 6 to 8 feet bgs. Hydraulic conductivity estimates in the Shallow Aquifer indicate at least a two-order-of-magnitude range from 1×10^{-2} to 1×10^{-4} centimeters per second (cm/sec), with interbedded lower-permeability silt and peat layers and high heterogeneity.
- **Deep Aquifer.** Occurs in the Deeper Alluvium to a depth of approximately 140 feet bgs. Hydraulic conductivity estimates for the Deep Aquifer average approximately 2×10^{-2} cm/sec.

The groundwater flow system includes recharge in the upland areas east of the Site and the May Creek drainage south/southeast of the Site, with flow toward the west and discharge to Lake Washington. Site groundwater originates from precipitation on and east of the Site and recharge from alluvial deposits in the May Creek drainage immediately south of the Site. The elevation of Lake Washington is controlled by the U.S. Army Corps of Engineers (USACE) and typically fluctuates up to 2 feet during the year. The lake level is typically lowest in the late fall and early winter, and highest during the late spring and summer.

Site groundwater generally flows horizontally across the Site in an east to west direction, ultimately discharging to Lake Washington. Based on the observed hydraulic gradient, the estimated time for groundwater to travel through the Deep Aquifer from the eastern property boundary to Lake Washington is approximately 5 years.

There is no continuous aquitard separating the Shallow and Deep Aquifers; however, the Deep Aquifer is considered to be a semi-confined aquifer, as the vertical hydraulic interaction between the Shallow and Deep Aquifers is limited by the horizontal stratification of the Shallow Alluvium, and varies depending on the location on the Site. Shallow groundwater in the eastern portion of the Site near the Railroad Property typically flows downward through the Shallow Aquifer into the upper portion of the Deep Aquifer. Within the central areas of the Site, groundwater flow is primarily horizontal, and vertical exchange between the Shallow Aquifer and Deep Aquifer is limited. Near the shoreline of Lake Washington, groundwater in the Deep Aquifer has an upward flow component and travels through the Shallow Aquifer before discharging to surface water.

Conceptual Site Model

The primary source of Site contamination is DNAPL that originated as creosote and other coal-tar products. DNAPL is present in the shallow subsurface in much of the upland area, extending nearshore beneath Lake Washington adjacent to Quendall Pond, and in surface sediment offshore along the location of the former T-Dock. The DNAPL tends to occur within discrete layers or thin lenses in the Shallow Alluvium rather than in continuous “pools.” The subsurface movement of DNAPL is influenced by the prevailing east-to-west groundwater flow direction, but the deltaic nature of the Shallow Alluvium (i.e., sloping and interbedded silt, sand, and peat layers) also plays a significant role in how DNAPL migrates in the subsurface. Boring and test pit logs indicate that DNAPL impacts approximately 9.7 acres of the Site and is present as deep as 34 feet bgs, but is most typically observed in the upper 20 feet bgs. Approximately 445,000 gallons of DNAPL are estimated to be present at the Site.

Contaminants in DNAPL migrate via a variety of transport mechanisms into other Site media, including soil, groundwater, sediment, and air. Where DNAPL is present, benzene, naphthalene, and carcinogenic polycyclic aromatic hydrocarbon (cPAH) concentrations are above preliminary remediation goals (PRGs) in groundwater, with impacted groundwater generally extending downgradient (both horizontally and vertically) from DNAPL-impacted areas. The migration of dissolved chemicals in groundwater is primarily controlled by the east-to-west groundwater flow direction and contaminant-specific mobility. Benzene and naphthalene are relatively mobile and, based on both empirical data and groundwater modeling, have likely migrated deeper and further downgradient from DNAPL source areas compared to the less mobile cPAHs.

Groundwater transport of soluble coal-tar product constituents from the Site uplands has also contributed contaminants to nearshore area sediment. Contaminated groundwater migration from DNAPL source areas represents a secondary contaminant source to soil and sediment.

Arsenic concentrations in groundwater also exceed the PRG in both the Shallow Alluvium and the Deeper Alluvium. These exceedances may be caused, at least in part, by mobilization of naturally occurring arsenic under reducing conditions, which occur in areas of soils containing DNAPL, dissolved-phase hydrocarbon contamination, and naturally high levels of organic carbon (e.g., peat).

A baseline human health risk assessment (HHRA) and an ecological risk assessment (ERA) were conducted in accordance with EPA guidance to identify Site chemicals of concern (COCs) and evaluate potential risks associated with their presence in Site media. The HHRA concluded that risks posed to human receptors exceed a cancer risk of one in ten thousand and/or a hazard quotient (HQ) of 1 for non-cancer risk. The human health risk drivers are benzene, naphthalene, cPAHs, and arsenic. The ERA concluded that risks to terrestrial invertebrates, plants, and wildlife (birds and mammals), as well as to benthic invertebrates, aquatic plants, and aquatic-dependent wildlife, exceed an HQ of 1. The ecological risk drivers are PAHs.

Remedial Action Objectives

Applicable or relevant and appropriate requirements (ARARs) were identified, and remedial action objectives (RAOs) and PRGs were developed for the Site in accordance with CERCLA guidance. RAOs and PRGs help define the extent of contaminated media requiring remedial action, and inform the development of remedial alternatives that will protect human health and the environment and comply with ARARs.

One of the expectations for remedial alternatives to be generally considered by EPA is the ability of remedial alternatives to address principal threat wastes (PTWs) to the extent practicable. PTWs are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to human health or the environment should exposure occur. For the purposes of this FS, DNAPL, DNAPL-impacted soil, and DNAPL-impacted sediment (i.e., either oil-wetted or oil-coated materials; also referred to as residual DNAPL or ‘DNAPL-impacted’ soil or sediment in this FS) are considered to be PTWs.

The RAOs for the Site are defined by EPA and listed below. The alternatives assembled in this FS use a wide range of removal, treatment, and containment strategies to address Site media, including PTWs.

The RAOs for the Site as defined by EPA are:

Source Control RAOs:

- **SC1: PTW.** Treat or remove DNAPL in subsurface soils and groundwater to prevent contamination of groundwater above COC maximum contaminant levels (MCLs) to the extent practicable.
- **SC2: PTW.** Contain DNAPL in subsurface soils and groundwater where treatment or removal is not practicable.
- **SC3: Soil.** Reduce migration of COCs to groundwater from soils that exceed remediation goals for the protection of groundwater.
- **SC4: Sediment.** Reduce migration of COCs to surface water from sediments that exceed remediation goals for the protection of surface water.

Human Health Protection RAOs:

- **HH1: Groundwater.** Restore groundwater to its highest beneficial use (drinking water) by meeting COC MCLs in the Site Shallow Alluvium and Deeper Alluvium aquifers within a reasonable period of time.
- **HH2: Sediment.** Reduce to acceptable levels the risk to adults and children who ingest resident fish and shellfish taken from the Site for subsistence.
- **HH3: Sediment.** Reduce to acceptable levels the human health risk from playing, wading, or swimming resulting in incidental ingestion or/and dermal exposure to contaminated sediments that exceed remediation goals.
- **HH4: Surface Water.** Reduce to acceptable levels the human health risk from direct contact or incidental ingestion of surface water contaminated with COCs exceeding remediation goals (water quality standards or MCLs).
- **HH5: Vapor.** Reduce to acceptable levels the human health risk from inhalation of vapors from groundwater and/or soils contaminated with COCs exceeding soil or groundwater remediation goals.
- **HH6: Soils (Surface and Subsurface).** Reduce to acceptable levels the human health risk from direct contact or incidental ingestion of COCs in soil exceeding soil remediation goals.

Environmental Protection RAOs:

- **EP1: Surface Water.** Reduce to acceptable levels the risk to aquatic-dependent organisms when direct contact with surface water or incidental ingestion of COCs in surface water exceeds remediation goals (water quality standards).
- **EP2: Upland Soil.** Reduce to acceptable levels the risk to terrestrial wildlife when direct contact and incidental ingestion or consumption of soil invertebrates results in exposures to COCs that exceed remediation goals.
- **EP3: Sediment.** Reduce to acceptable levels the risk to aquatic-dependent wildlife (sediment probing birds and piscivorous mammals) and benthos where surface sediments containing COCs exceed remediation goals.

Site Areas and Media Targeted for Remedial Action

Site areas targeted for remedial action, including areas containing DNAPL and areas with contaminant concentrations above PRGs, are shown on Figure ES-3.

DNAPL areas—differentiated based on location-specific DNAPL depth, mobility, thickness, and effect on groundwater quality—were designated as follows:

- **RR DNAPL Area:** DNAPL-impacted soil in the former Railroad Tank Car Loading Area (deep occurrence, maximum thickness, and potentially mobile);
- **MC DNAPL Area:** DNAPL-impacted soil in the former May Creek Channel (deepest occurrence, moderate thickness, and potentially mobile);
- **QP-U DNAPL Area:** DNAPL-impacted soil around Quendall Pond (deep occurrence, moderate thickness, and potentially mobile);
- **QP-S DNAPL Area:** DNAPL-impacted sediments offshore of Quendall Pond (moderate depth and thickness, and potentially mobile); and
- **TD DNAPL Area:** DNAPL-impacted sediments along the former T-Dock (shallow sediment depth and moderate thickness).

Areas with DNAPL at shallow to moderate depth in the uplands with fewer occurrences of oil-wetted DNAPL were grouped separately and are described as Other Upland or Aquatic DNAPL Areas, as they are more challenging to delineate individually and they share similar characteristics. In the uplands, these areas include DNAPL-impacted soil in other former process areas, specifically the Still House, the Boiler House, and the North and South Sumps). Many of the Other Upland DNAPL Areas contain DNAPL with significant cumulative thickness. Offshore, these generally include areas between the TD and QP-S DNAPL Areas.

Key factors influencing the remediation of DNAPL at the Site are as follows:

- EPA has determined that DNAPL at the Quendall Site, whether in soils or sediments, is to be considered as PTW because of the high level of toxicity inherent in the creosote/coal tar DNAPL. Creosote/coal tar contaminants present in DNAPL (benzene and naphthalene) are also highly leachable and mobile via groundwater, and DNAPL classified as oil-wetted may be also be mobile.
- DNAPL at the Site cannot be reliably contained because any vertical barrier/treatment wall that would be installed at the Site could only be a “hanging” wall. There is no aquitard in which to anchor a barrier/treatment wall.
- DNAPL is accessible. The majority of DNAPL in the uplands is found within the top 20 feet of the Shallow Aquifer with two exceptions (RR Area and Former May Creek Channel).

Figure ES-4 provides a cross section, oriented as shown on Figure ES-3, with delineated DNAPL areas highlighted. Site areas were also differentiated with respect to DNAPL cumulative thickness.

PRG-exceedance areas were designated as follows based on type of media impacted and depth of contamination:

- The Surface Soil Area;
- The Subsurface Soil and Groundwater Area; and
- The Surface and Subsurface Sediment Area.

In addition, EPA has identified the entire Quendall shoreline and landward 100 feet as the habitat corridor that will be the location for wetland mitigation.

Technology Identification and Screening

Remedial technologies and process options were identified and screened for their potential effectiveness in satisfying the Site RAOs. For each contaminated medium (DNAPL, soil, groundwater, and sediment), remedial technologies were first evaluated with respect to their potential applicability to Site conditions and COCs. Remedial technologies retained from this initial screening were then evaluated relative to one another based on their potential effectiveness, implementability, and cost. For remedial technologies that were retained, one representative process option within a given technology group was identified for the purposes of developing remedial alternatives for evaluation in this FS. After EPA selects a Site remedy, other process options may be re-evaluated during remedial design to optimize the final remedy. The following technologies and process options were used to assemble remedial alternatives:

- Upland excavation to remove source material with either off-site disposal or on-site *ex situ* thermal treatment;
- DNAPL collection trenches to remove mobile DNAPL from the subsurface and further reduce the potential migration of DNAPL from the uplands to the lake sediments;
- A funnel and gate system using a passive reactive barrier (PRB) to reduce migration of contamination in groundwater from the uplands and aid in the recovery of lake sediments and porewater;
- Upland cap to protect human health from direct contact with contaminated surface soils;
- Dredging of sediment PTW with either off-site disposal or on-site *ex situ* thermal treatment; placement of reactive residuals covers over dredged areas to manage residuals if necessary;
- Reactive core mat (RCM) caps over aquatic PTW areas to sorb DNAPL and control DNAPL migration;
- Enhanced natural recovery (ENR) to remediate areas of low concentration of cPAHs in sediment;
- Engineered sand cap to remediate sediment areas impacted by upwelling contaminated groundwater;

- Institutional controls to help ensure the effectiveness of engineering controls; and
- Monitoring to verify that the remedy is performing as intended.

Development of Remedial Alternatives

Retained remedial technologies and process options were assembled into the following alternatives. To assist the reader, descriptive titles for the numbered alternatives are provided below with the areas that are the primary focus of the remedy listed in parentheses.

- **Alternative 1 – No Action**
- **Alternative 2 – Containment:** permeable soil, engineered sand, and RCM sediment capping
- **Alternative 3 – Targeted PTW[1] Solidification (RR and MC-1 DNAPL Areas):** targeted treatment of two areas of deep upland PTWs via *in situ* solidification, passive groundwater treatment, and soil and sediment capping
- **Alternative 4 – Targeted PTW Removal (TD, QP-S, and QP-U DNAPL Areas):** targeted treatment of three areas of PTWs via removal/off-site disposal, passive groundwater treatment, and soil and sediment capping
- **Alternative 4a – Targeted PTW Solidification (QP-U, RR and MC-1 DNAPL Areas) and Removal (TD DNAPL Area):** targeted treatment of two areas of deep upland PTWs and one nearshore upland PTW area via *in situ* solidification, targeted treatment of one area of sediment PTWs via removal/off-site disposal, passive groundwater treatment, and soil and sediment capping
- **Alternative 5 – Targeted PTW Solidification (RR, MC, and QP-U DNAPL Areas and ≥ 4-Foot-Thickness) and Removal (TD and QP-S DNAPL Areas):** targeted treatment of multiple upland areas of PTWs via *in situ* solidification and targeted removal/off-site disposal of sediment PTWs, passive groundwater treatment, and soil and sediment capping
- **Alternative 6 – Targeted PTW Solidification (RR and MC DNAPL Areas and ≥ 2-Foot-Thickness) and Removal (TD, QP-S, and QP-U DNAPL Areas):** targeted treatment of multiple upland areas of PTWs via *in situ* solidification and targeted removal/off-site disposal of upland and sediment PTWs, passive groundwater treatment, and soil and sediment capping

[1] PTWs for the Site include DNAPL, DNAPL-impacted soil, and DNAPL-impacted sediment (see Section 4.2). Upland PTWs include DNAPL and DNAPL-impacted soil located east of the shoreline. Sediment PTWs include DNAPL and DNAPL-impacted sediment west of the shoreline.

- **Alternative 7 – PTW Solidification (Upland) and Removal (Sediment):** treatment of all upland PTWs via *in situ* solidification, treatment of all sediment PTWs via removal/off-site disposal, and soil and sediment capping
- **Alternative 8 – PTW Removal (Upland and Sediment):** treatment of all upland and sediment PTWs via removal/on-site *ex situ* thermal treatment, and soil and sediment capping
- **Alternative 9 – Solidification and Removal of Upland PTW and Contaminated Soil, and Removal of Sediment PTW and Contaminated Sediment:** treatment of all upland PTWs and contaminated soil via *in situ* solidification or removal/on-site *ex situ* thermal treatment, treatment of all sediment PTWs and contaminated sediment via removal/on-site *ex situ* thermal treatment, and soil and sediment capping
- **Alternative 10 – Removal of Upland PTW, Sediment PTW, Contaminated Soil, and Contaminated Sediment:** treatment of all PTWs and contaminated soil and sediment via removal/on-site *ex situ* thermal treatment, and soil and sediment capping

Table ES-1 summarizes how retained technologies and process options were assembled into these alternatives. Groundwater and sediment cap modeling was used to help develop alternatives in two ways: 1) to evaluate how Site-wide alternatives could be structured to meet RAOs, and 2) to provide conceptual design criteria for the purpose of developing alternatives and estimating costs. Also, for the purposes of the FS, it was assumed that the habitat area would consist of a 100-foot-wide corridor along the shoreline and be composed of a mixture of wetlands and riparian habitat. There would be limitations on allowable work within the area and remedial components requiring future access for monitoring or maintenance, such as PRBs or groundwater extraction wells, would be placed outside and east of the habitat area.

The components of Alternatives 2 through 10 are depicted on Figures ES-5 through ES-14, respectively.

Detailed and Comparative Analysis of Alternatives

The NCP remedy selection criteria include the following:

Threshold Criteria

1. Overall protection of human health and the environment;
2. Compliance with ARARs;

Balancing Criteria

3. Long-term effectiveness and permanence;
4. Reduction of toxicity, mobility, or volume through treatment;
5. Short-term effectiveness;

6. Implementability;
7. Cost;

Modifying Criteria

8. State and tribal acceptance; and
9. Community acceptance.

Consistent with 40 CFR 300.430, each alternative is first evaluated using the threshold criteria of Overall Protectiveness of Human Health and the Environment and Compliance with ARARs. For threshold criteria, each alternative is identified as meeting or not meeting the criteria. The alternatives that meet the threshold criteria are evaluated further with respect to the balancing criteria. For all of the balancing criteria except cost, each alternative is evaluated using a qualitative scale to rate the relative degree (i.e., low, moderate, high) to which the alternative meets the requirements of that criterion. For cost, the evaluation is based on estimated capital and long-term operation, maintenance, and monitoring (OM&M) costs[2]. The two modifying criteria are evaluated by EPA at a later stage in the CERCLA process.

A summary of the comparative rating of alternatives is provided in Table ES-2. Results of the comparative analysis are discussed below.

Threshold Criteria Comparison

This section presents a comparative analysis of the two threshold criteria: Overall Protection of Human Health and the Environment, and Compliance with ARARs.

Overall Protection of Human Health and the Environment

This threshold criterion addresses the overall ability of each alternative to eliminate, reduce, or control potential exposures to hazardous substances in both the short and long term, and comply with ARARs, and evaluates whether the alternative achieves the RAOs for protection of human health and the environment.

The adequacy of how the risks associated with the exposure pathways delineated in the RAOs for protection of human health and the environment are eliminated, reduced, or controlled through treatment, engineering, or institutional controls for each alternative describes its **protectiveness**. However, the **Overall Protectiveness** threshold criterion draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs. The Overall Protectiveness of Human Health and the Environment criterion was rated as “No,” or “Yes,” based on consideration of whether: 1) all exposure pathways are mitigated (i.e., the alternative is protective); 2) the alternative provides long-term effectiveness and permanence; 3) does not pose a high short-term risk; and 4) meets ARARs or is waived from the requirement for compliance with an ARAR.

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[2] Note that the cost effectiveness of the remedial alternatives is not evaluated in the FS but will be considered during selection of a preferred remedy.

RAOs for Protection of Human Health

Alternative 1 does not achieve any of the RAOs for protection of human health. Alternatives 2 through 6 will achieve the RAOs for human health that focus on protection of beach users, subsistence fishers, upland residents, commercial workers, and construction workers. However, the RAO to restore groundwater to its highest beneficial use (drinking water) by meeting MCLs cannot be achieve by Alternatives 2 through 6 because PTWs that cause the groundwater contamination remain in place to varying degrees. Alternatives 7 through 10 treat or remove all known PTWs[3], and therefore, may restore groundwater to meet drinking water standards for one or more COCs throughout most of the plume, if not all of the plume (see Figure ES-15). For these alternatives, institutional controls that specifically address use of drinking water would not be fully required in perpetuity.

There would be a heavier reliance on institutional controls that would control the disturbance of the soil cap from activities that may compromise the integrity of the soil cap for Alternatives 2 through 6; whereas a soil cap may not be needed for Alternatives 7 through 10, where all PTWs are removed or treated[4]. Alternatives 2 through 10 would all initially rely on institutional controls to control exposure to contaminated sediment and surface water by restricting activities that could cause damage to sediment caps that mitigate the release of contamination into surface water. However, there would be a lesser reliance on caps and they may not be required in perpetuity for Alternatives 7 through 10 because all PTWs are removed from the aquatic environment.

RAOs for Protection of the Environment

Alternative 1 does not achieve any of the RAOs for protection of the environment. Alternatives 2 through 10 will achieve the RAOs for the environment that focus on protection of upland wildlife and plants, as well as aquatic benthos, fish, plants, and aquatic-dependent wildlife. There would be a heavier reliance on institutional controls would control the disturbance of the soil cap from activities that may compromise the integrity of the soil cap for Alternatives 2 through 6; whereas a soil cap may not be needed for Alternatives 7 through 10, where all known PTWs are removed or treated. Alternatives 2 through 10 would all rely on institutional controls to control exposure to contaminated sediment and surface water by restricting activities that could cause damage to sediments caps that mitigate the release of contamination into surface water. However, there would be a lesser reliance on caps in perpetuity for Alternatives 7 through 10 because all known PTWs are removed from the aquatic environment.

Overall Protection of Human Health and the Environment Summary

Alternatives 1 through 6 would not meet this threshold criterion because they leave varying amounts of known and accessible PTWs in place and as a result, will never

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[3] All "known PTWs" refers to PTWs identified during site investigations supporting the FS. It is anticipated that the lateral and vertical extent of PTWs in both the upland and aquatic areas of the Site will be based on a field performance standard that would be developed during remedial design. It is also anticipated that small volumes and masses of DNAPL residuals could be inadvertently missed during remedial implementation.

[4] A full upland soil cap may not be necessary in other alternatives where portions of the upland soils have been excavated or treated, and therefore, do not pose a dermal or inhalation exposure risk.

restore groundwater to its highest beneficial use and rely heavily on institutional controls to be protective. Alternatives 7 through 10 would meet this threshold criterion because all known PTWs are removed or treated. They would also likely comply with the MCL ARAR (see next section), and in the event MCLs are not determined to be achievable for all COCs, Alternatives 7 through 10 would be candidates for a Technical Impracticability (TI) waiver, as all known PTWs are addressed under these alternatives.

Compliance with ARARs

This threshold criterion assesses whether each alternative would attain the identified chemical-, action-, and location-specific ARARs and other “To Be Considered” (TBC) criteria, advisories, and guidance presented in Section 4.1. As discussed in Section 7.1.1.2, it would be expected that all alternatives, except Alternative 1 (No Action), would comply with all ARARs except the Safe Drinking Water Act (SDWA), which requires achievement of groundwater MCLs throughout the Site. The degree to which MCLs would be achieved varies dramatically based on the PTWs addressed for each alternative.

As described in Section 7.1.1.2, the Compliance with ARARs criterion was rated as “No”, “Yes with TI Waiver”, or “Yes”.

Compliance with the MCL ARAR

To assess compliance with the SDWA, groundwater modeling was used to predict the volumes of contaminated groundwater exceeding the MCLs for benzene, benzo(a)pyrene, and arsenic 100 years following implementation of each alternative. Results are provided on Figure ES-16 and are summarized below:

- Benzene was predicted to exceed its MCL after 100 years for Alternatives 1 through 7 and 9. It was predicted to achieve its MCL after 28 years for Alternative 8, and after 14 years for Alternative 10. EPA believes that the timeframes for Alternatives 8 and 10 may also be relevant for Alternatives 7 and 9, given that the extent of benzene MCL exceedances based on empirical data are smaller than the model predicts, *in situ* solidification is likely to oxygenate the subsurface and aid in volatile attenuation, and the resulting solidified materials are not considered to be aquifer materials.
- Benzo(a)pyrene was predicted to exceed its MCL in groundwater after 100 years for all alternatives except for Alternative 10. For Alternative 10, the groundwater model predicted that the benzo(a)pyrene MCL would be achieved when construction is complete. EPA believes that the benzo(a)pyrene MCL could also be achieved in a reasonable timeframe with Alternatives 7, 8, and 9. Empirical data indicate there are currently a few instances of very low detections of benzo(a)pyrene above the MCL outside the known DNAPL areas. The reason the groundwater model predicts MCL exceedances after 100 years for Alternatives 7, 8, and 9 is that it assumes a baseline condition where benzo(a)pyrene exceeds the MCL outside of the DNAPL areas; therefore, even when the DNAPL source is removed, the model assumes that the MCL exceedances remain and do not degrade over time. Based on empirical data, EPA believes that if the DNAPL source is addressed, then benzo(a)pyrene would also be addressed.

- Arsenic was predicted to exceed its MCL in groundwater 100 years following implementation of all alternatives. For Alternatives 7 through 10, EPA believes that if the known DNAPL source is removed or treated, arsenic will also be more significantly reduced than the modeling predicts.

Alternative 2 slightly reduced the estimated volume of groundwater exceeding MCLs after 100 years (by 13 percent for the aggregate plume). Alternative 1 (No Action) is used as a baseline against which the plume reductions achieved by the other alternatives are compared. The volume of groundwater exceeding MCLs after 100 years would be moderately reduced by implementing Alternatives 3 through 6 (ranging from 33 to 50 percent aggregate reduction) and significantly reduced by implementing Alternatives 7 through 10 (ranging from 79 to 93 percent aggregate reduction).

Technical Impracticability Waiver

Alternatives 1 through 6 would require a TI waiver to meet statutory requirements for selecting a remedial action. It is also assumed that a TI waiver would not be granted because the PTW is readily accessible and removal or treatment is feasible with currently available engineering technology. Alternatives 7 through 10 may or may not require a TI waiver; however if a TI waiver was needed, a TI waiver could be granted for Alternatives 7 through 10.

Compliance with ARARs Summary

Alternatives 1 through 6 do not satisfy the threshold criteria for compliance with the ARARs. The MCLs for benzene, benzo(a)pyrene, and arsenic will not be met throughout the plume nor can a TI waiver be granted. Alternatives 7 through 10 may achieve MCLs for one or more COCs in a reasonable timeframe, and if necessary, a TI waiver could be granted.

Threshold Criteria Summary

Overall protection of human health and the environment and compliance with ARARs serve as threshold determinations in that they must be met by any alternative in order for it to be eligible for selection. The Site has some recalcitrant COCs and a very complex, heterogeneous subsurface. Both contribute to challenges in developing and selecting remedial alternatives that are appropriate to the Site. Conversely, based on years of site investigations culminating with the RI in 2009, it has been determined that the extent of PTWs at the Site is limited to shallow (less than 35 feet) alluvium and is accessible (as opposed to, for example, deep in fractured bedrock). EPA agreed during the FS scoping process to allow development of a wide array of alternatives to address the remedial problems at the Site even though it was uncertain prior to the evaluation of alternatives whether any of the alternatives would satisfy threshold criteria and potentially require a waiver of ARARs.

As described above, Alternatives 1 through 6 do not meet either threshold criteria. However, Alternatives 7 through 10 satisfy the overall protection of human health and the environment criterion, and would meet all ARARs or be granted a TI waiver if monitoring indicated that one or more of the COCs in groundwater would not achieve MCLs. Section 7 includes the detailed analysis used to evaluate these threshold criteria that drew on evaluation of the balancing criteria and interpretation of groundwater modeling. Because Alternatives 1 through 6 do not satisfy the threshold criteria, they are not carried forward in the Balancing Criteria comparison.

Balancing Criteria Comparison

Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence rating is based on consideration of both the magnitude of residual risk associated with any contamination remaining at the Site following implementation of the remedy and the reliability of controls.

The differences in long-term effectiveness and permanence among the alternatives are summarized as follows:

- Alternatives 7 through 10 would greatly reduce the magnitude of residual risk through removal or treatment of all known PTWs.
- Alternatives 9 and 10 remove or treat additional contaminated soil and sediment, but the vast majority of the contaminant mass is present in the PTWs. With the exception of a smaller residual arsenic plume for Alternative 10, all of these alternatives provide for similar and substantial reductions in the volume of contaminated groundwater.
- Alternatives 7 through 10 would include similar engineering and institutional controls; however, the controls would be more effective for Alternatives 9 and 10, where the remedies would reduce the quantity of contamination remaining. For instance, there is less risk in the event of technology failure (e.g., cap disturbance during a seismic event or violation of restrictive covenants) if there is less residual contamination. In the event that a control measure fails, all alternatives would have monitoring to identify the failure and to repair the measures.
- Alternatives 7 through 10 are all rated high for this criterion.

The magnitude of residual risk was evaluated in the context of achieving RAOs, and considered the total volume of DNAPL removed or treated in each alternative (Figure ES-15).

Reduction of Toxicity, Mobility, or Volume through Treatment

This balancing criterion evaluates the degree to which each remedial alternative reduces toxicity, mobility, or volume through treatment. Alternatives 7 through 10 would employ two treatment methods for PTW:

- *In situ* solidification of upland PTWs (Alternatives 7 and 9); and
- On-site thermal treatment of PTWs (Alternatives 8, 9, and 10).

For the purposes of this FS, treatment by thermal destruction technologies (incineration/ thermal desorption) was rated higher than *in situ* solidification, because preference was given to technologies that permanently destroy the COCs (thus reducing toxicity, mobility, and volume) over technologies that permanently bind COCs.

Groundwater treatment would be achieved through treatment of PTWs and surrounding contaminated soil or sediment as described above. In addition, groundwater pump and treatment systems would be used to treat Site groundwater along the shoreline for Alternative 10.

Alternatives 7 through 10 were rated with respect to this criterion as follows:

- Alternatives 7 and 8 would treat all PTWs and greatly reduce the volume and mass flux of contaminated groundwater. Alternative 7 would achieve treatment through *in situ* solidification, while Alternative 8 would achieve treatment through on-site thermal treatment. Both alternatives are rated high for this criterion. Alternative 8 satisfies this criterion to a slightly higher degree than Alternative 7 due to the more permanent nature of treatment and reduction in contaminant volume.
- Alternatives 9 and 10 would treat all PTWs and also would treat a substantial volume of contaminated soil and sediment. Alternative 9 would use a combination of *in situ* solidification and on-site thermal treatment, while Alternative 10 would use on-site thermal treatment. Alternative 10 also would achieve the greatest reduction in groundwater plume volume.
- Alternatives 7 through 10 are rated high for this criterion.

Short-Term Effectiveness

This balancing criterion is used to evaluate the effects and potential risks associated with remedial alternative implementation, considering the protection of the community, the protection of workers, and potential impacts to the environment. This criterion also considers the effectiveness of mitigative measures (i.e., measures such as BMPs that would reduce the short-term impacts of the alternatives) and the time until RAOs would be achieved.

In general, short-term impacts increase with the quantities of contaminated materials removed or handled. Many impacts can be adequately managed through standard construction practices such as health and safety programs and BMPs, but the potential for increased exposures, or releases to the neighboring community, on-site workers, and the environment could occur due to failure of construction equipment and/or protective controls when remediating greater volumes of contaminated materials. In addition, several impacts would be challenging to control, including the following:

- Vapor and dust emissions, from disturbance of contaminated materials during excavation, dredging, and (to a lesser degree) *in situ* solidification. These could result in noxious odors and exposure of the community to volatile compounds.
- Vapor and dust emissions from handing, stockpiling, and transporting contaminated materials off-site (Alternative 7).
- Alternatives involving on-site thermal treatment of contaminated materials (Alternatives 8, 9, and 10) also would have the potential for air emissions from on-site handling and treatment; however, these emissions would be more easily controlled by available process technologies employed in the treatment train.
- Water quality impacts from capping and dredging would be reduced as much as possible by implementing hydraulic dredging with silt curtain/oil boom controls in the aquatic area and providing barrier containment with sheet piles around mechanical dredge areas in the nearshore.

- RAOs, with the exception of restoring groundwater to its highest beneficial use, would be achieved at the end of the construction period. Meeting this RAO would require an uncertain period of time following the end of construction, but it is assumed that either MCLs would be met for one or more COCs in a reasonable timeframe, or a TI waiver could be granted, if necessary.
- "Quality of life" impacts to the community from construction noise, traffic, and aesthetics could result. However these are not related to risks caused from potential exposure to contaminated media.

The short-term effectiveness of Alternatives 7 through 10 is compared in Table ES-2 and summarized as follows:

- Alternative 7 involves *in situ* stabilization of known upland PTWs and dredging of known aquatic PTWs and would have a construction period of approximately 4.5 years. Dredged materials would be trucked offsite for disposal. These activities all create the potential for exposure to dust and vapors for both the community and Site workers; however no unacceptable risk is expected to the community or workers because of the use of protective equipment and practices. The greatest impacts would be expected in the aquatic environment; however, BMPs will be used to minimize water quality impacts, and habitat recovery is expected to occur relatively quickly following placement of the residuals cover over dredged areas. Therefore, Alternative 7 is rated as moderate for short-term effectiveness.
- Alternative 8 involves excavation of upland PTWs, the same dredging of PTW sediments as Alternative 7, and on-site thermal treatment of all removed PTW materials. Alternative 8 would have a longer construction period (approximately 5.5 years). It would include additional materials handling and stockpiling of PTW materials, as well as air emissions from on-site treatment; therefore, it would likely have higher short-term impacts than Alternative 7. Alternative 8 is rated low for short-term effectiveness.
- Alternatives 9 and 10 would have the greatest potential short-term impacts to workers, the community, and the environment, and would have very long construction durations (10 and 12 years, respectively). Therefore, they are rated low for short-term effectiveness. Alternative 10 would have greater short-term impacts than Alternative 9 due to the much greater volumes of contaminated soil and sediment that would be removed under Alternative 10.

Implementability

This balancing criterion is used to evaluate the relative implementability of Alternatives 7 through 10, focusing on their technical feasibility, administrative feasibility; and the availability of services and materials.

In general, implementability decreases with increased complexity of the alternatives. With the exception of the RCM caps, the technologies used by all alternatives are proven technologies that have been implemented at other, similar sites and could be implemented at the Site. Differences in complexity include the following:

- Alternatives involving *in situ* solidification (Alternatives 7 and 9) would require bench and/or pilot testing of potential amendment mixtures to determine proper mixes to optimize effectiveness, though this is not considered to be an implementability concern.
- Alternatives involving deep excavations (Alternatives 8 and 10) would have substantially increased complexity due to robust shoring and dewatering systems. The conceptual shoring system for Alternative 10 would include 95-foot-long sheet piles (based on the analysis performed in Section 6), which are not readily available and could result in transportation challenges.
- Alternatives involving on-site thermal treatment of soil or sediment (Alternatives 8, 9, and 10) would require treatability testing. On-site thermal treatment would also require air emission controls and extensive monitoring.

All alternatives would require coordination with numerous federal and state regulatory agencies, during remedial design, to ensure that all ARARs (including ESA consultation and substantive compliance with Section 401 and 404 of the CWA), policies, and regulations are met. Coordination with these agencies, by EPA, has become routine in the Puget Sound area of Washington. Little coordination is expected during remedial action because reasons for coordination would be addressed during remedial design. Maintenance of caps would require coordination with the Department of Natural Resources (DNR) and the Muckleshoot Tribe regarding future aquatic land use and Tribal treaty rights. Alternatives with longer construction durations and/or more construction elements would generally require more administrative coordination and have a greater potential for technical problems and schedule delays.

The implementability of each alternative is compared in Table ES-2 and summarized as follows:

- Alternative 7 would have the shortest construction period and the fewest construction elements compared to Alternatives 8 through 10. This alternative is rated high for implementability.
- Alternative 8 would involve significantly greater implementability challenges than Alternative 7 due to the complexities of shoring and dewatering extensive excavations and providing on-site thermal treatment of a large volume of material. This alternative is rated low for implementability.
- Alternatives 9 and 10 would involve the largest soil and sediment removal volumes and very extensive in-water and upland construction activities. The scope of these activities would encounter severe technical and administrative challenges. These alternatives are rated low for implementability.

Cost

The estimated present worth cost for each alternative, in 2013 dollars and using a discount factor of 1.6 percent, is listed in Table ES-2. Capital and OM&M costs are also provided in Table ES-2. Alternative costs ranged as follows:

- Alternative 7 capital ($78M) and total ($80M) costs are based on treatment of all upland PTWs via *in situ* solidification. The OM&M cost ($2.7M) is based on groundwater monitoring and inspection/maintenance of the upland cap, engineered sand cap, and ENR.

- Alternative 8 would have much higher capital ($137M) and total ($140M) costs than Alternative 7 because treatment of the same amount of PTWs would be accomplished using removal and on-site treatment, which has a much higher unit cost than *in situ* solidification. The OM&M cost ($2.7M) is the same as Alternative 7.
- Alternative 9 would have significantly higher capital ($259M) and total ($262M) costs compared to Alternative 8 because of the much more extensive treatment through *in situ* solidification of deep soil and removal/on-site treatment of contaminated sediments. The OM&M cost ($2.7M) is the same as Alternatives 7 and 8.
- Alternative 10 would have the highest capital ($380M) and total ($409M) costs of the alternatives. These costs are much higher than Alternative 9 because all contaminated soils would be removed and treated onsite, which has a greater unit cost than *in situ* solidification. The OM&M cost ($29M) is much higher because of long-term operation of a groundwater pump-and-treat system.

Comparative Analysis Summary

In this FS, 11 remedial alternatives were developed and evaluated as described above. The alternatives provide a broad range of actions, including various levels of containment, removal, and/or treatment, consistent with EPA guidance.

Alternatives 1 through 6 do not meet the threshold requirements for overall protectiveness and ARAR compliance. However, Alternatives 7 through 10 satisfy both the overall protection of human health and the environment criterion, and would meet all ARARs or be granted a TI waiver if monitoring indicates that one or more of the COCs in groundwater would not achieve MCLs. Because Alternatives 1 through 6 do not satisfy the threshold criteria, only Alternatives 7 through 10 were carried forward in the Balancing Criteria comparison.

Alternatives 7 through 10 are all rated high for long-term effectiveness and permanence, and reduction of toxicity, mobility, or volume through treatment. For short-term effectiveness, Alternative 7 is rated moderate, while Alternatives 8 through 10 are rated low. For implementability, Alternative 7 is rated high, while Alternatives 8 through 10 are rated low. Alternative 7 is projected to have the lowest cost. Alternative 8 is nearly twice the cost of Alternative 7; Alternatives 9 and 10 are approximately 3 and 5 times higher than Alterative 7.

EPA will select a preferred remedy and prepare a proposed plan based on the analysis presented in this FS, risk management considerations, and statutory requirements for remedial actions. The preferred remedy may be one of the alternatives described in the FS or a combination of elements from different alternatives, as appropriate. State, tribal, and community acceptance of the preferred remedy will be evaluated in the ROD once comments on the FS and proposed plan are received.